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Experience Report from Developing and Fielding the First SCA 2.0 JTRS Radio

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Agenda

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- Joint Tactical Radio System (JTRS) Overview
- JTRS Architecture
- JTRS Step 2c Radio Overview
- Fielding a JTRS Radio
- The SCA and the OMG
- Summary/Conclusion
- Questions?

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Joint Tactical Radio System (JTRS) Overview

Joint Tactical Radio System (JTRS) – Why?

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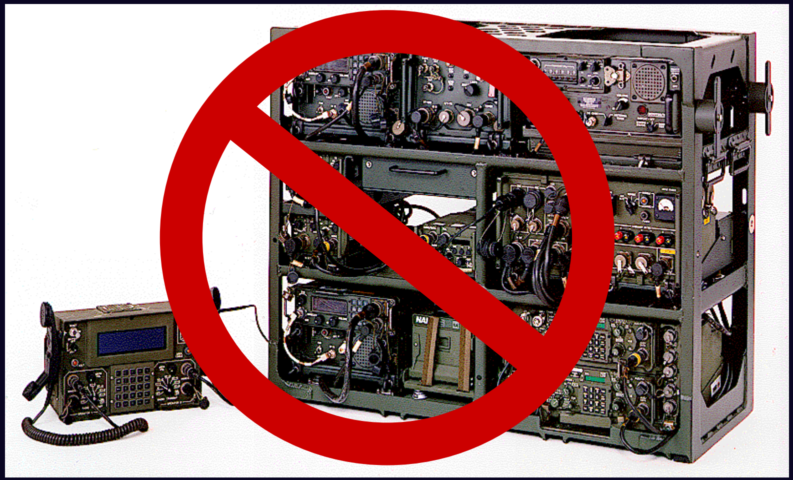
DoD mandate for JTRS:

"We can't support all your discrete radios"

"We can't fight the way we want to with your discrete radios"

"We can't introduce new technology at the pace of commercial industry"



Description

A DOD Joint Program for an information warfare communication system built on a family of HF-to-L-band radios with a common open architecture

Discriminators

- Software controlled and reprogrammable
- Modular and scaleable
- Extensive use of COTS technology
- Simplified applications engineering
- Rapid deployment of system improvements

Radio technology trends

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	1980's	1990's	2000's
Radio Architecture	Mostly Hardware	Mostly Software Platform-dependent (not portable)	Mostly Software Platform-independent Based on common architecture (portable)
Frequency Band/Channels	Single frequency band Single Channel	Multiple frequency bands Single channel	Multiple frequency bands Multiple channels
Services	Voice, Data	Voice, Data	Voice, Data, IP Services (Video, VoIP, etc)
Technology	DSPs, ASICs, Discrete components	DSPs, PLDs, ASICs	General Purpose Processors, FPGAs, DSPs
Upgrades	Hardware upgradeable (return to factory and retrofit)	Statically software upgradeable (still requires return to factory)	Dynamically software upgradeable (in the field)

What is a JTRS Radio?

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- **It's a Software Defined Radio !**

Meaning….

- It's Programmable!
  - Can be altered to implement both legacy communication systems as well as those yet to be defined
- It's Reconfigurable!
  - Supports dynamic partitioning of radio resources and re-characterization of radio in response to user needs.
- It's Upgradeable!
  - New or improved hardware and software capabilities are easily incorporated.
- It's Flexible!
  - Can operate in the commercial and military sector.
- It's Agile!
  - Can dynamically modify its operation in response to changes in environment.

How do you make a JTRS?

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- **Four of the top defense radio manufacturers get together and define a standard software architecture**
  - ➢ The Modular Software-programmable Radio Consortium (MSRC)
    - Raytheon, BAE SYSTEMS, Rockwell-Collins, ITT
- **The Software Communications Architecture (SCA)**
- **The SCA enables:**
  - ➢ Porting of waveforms across diverse radio platforms
  - ➢ Reuse of common software across these platforms
  - ➢ Scalability in the quantity of radio channels
  - ➢ Scalability across radio platforms
    - Same architecture from handheld to basestation
  - ➢ Maximum independence of software from specific hardware solutions
  - ➢ Use in both military and commercial sectors due to standardization activities performed by the OMG's Software Radio DSIG and the SDR Forum

How do you make a JTRS?

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- **How does the SCA enable such things?**
  - It specifies a common distributed, embeddable, object-oriented, language independent, platform-independent framework!
    - Allows you to deploy, configure, and tear down embedded radio applications
  - It specifies a component model which works in concert with the framework!
    - Provides a standard way to package and deploy real-time, multi-threaded, high performance radio components onto an SCA compliant radio platform.
  - It specifies common software interfaces!
    - Supports installation, radio domain management, and radio/waveform configuration
  - It provides a security architecture!
    - For systems requiring cryptography

And then What?

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- **Set out on a phased development to prove the architecture works**
- **JTRS Step 1 – Architecture Development**
  - MSRC members develop initial architecture
- **JTRS Step 2a – Architecture Feasibility**
  - MSRC Members deliver prototype radios -- SCA core framework and waveform implementations
  - Specification Maturation
  - Pursue commercial acceptance (OMG/SDR Forum)
- **JTRS Step 2b – Independent Architecture Validation**
  - Non-MSRC members deliver prototype radios
    - Harris/General Dynamics deliver prototype radios
    - Boeing – Delivers SCA core framework
    - Thales/Vanu provides handheld radios
    - Rockwell-Collins provides prototype waveform software
- **JTRS Step 2c – Ruggedized fieldable radio**
  - BAE SYSTEMS chosen to deliver SCA compliant radios for field evaluation
  - First JTRS radio to provide security features and networking capabilities

JTRS Architecture

What is the JTRS Software Architecture?

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- **Core Framework (CF)**
  - The essential, set of open software Interfaces and Profiles that provide for the deployment, management, interconnection, and intercommunication of software application components in embedded communication systems.
  - CF Interfaces consist of Base Application Interfaces, Framework Control Interfaces, Framework Service Interfaces use CORBA to communicate between radio entities.
- **Domain Profile**
  - XML files that describe:
    - The individual components of a software application
    - How the components are interconnected
    - The component properties.
    - The properties of hardware device abstractions.
- **Operating Environment (OE) – forms radio platform**
  - Core Framework
  - CORBA middleware (software bus)
  - Application Environment Profile
    - Defined by SCA to provide minimum operating system functionality
  - Operating System
  - Device Drivers

SCA Mandates

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- **RTOS**
  - RTOS Must Support SCA Application Environment Profile (AEP)
  - The SCA AEP is a subset of the POSIX.13 Real-time Controller System Profile (PSE52)
  - Applications are limited to using the RTOS services that are designated as mandatory in the SCA AEP
- **CORBA**
  - No extensions and/or services beyond Minimum CORBA can be used except as specified in the SCA.
    - e.g. Naming Service, Event Service)
  - Desired extensions listed as optional, pending commercial availability
    - Interoperable Naming Service
    - Real-Time CORBA
    - CORBA Messaging

SCA Layering

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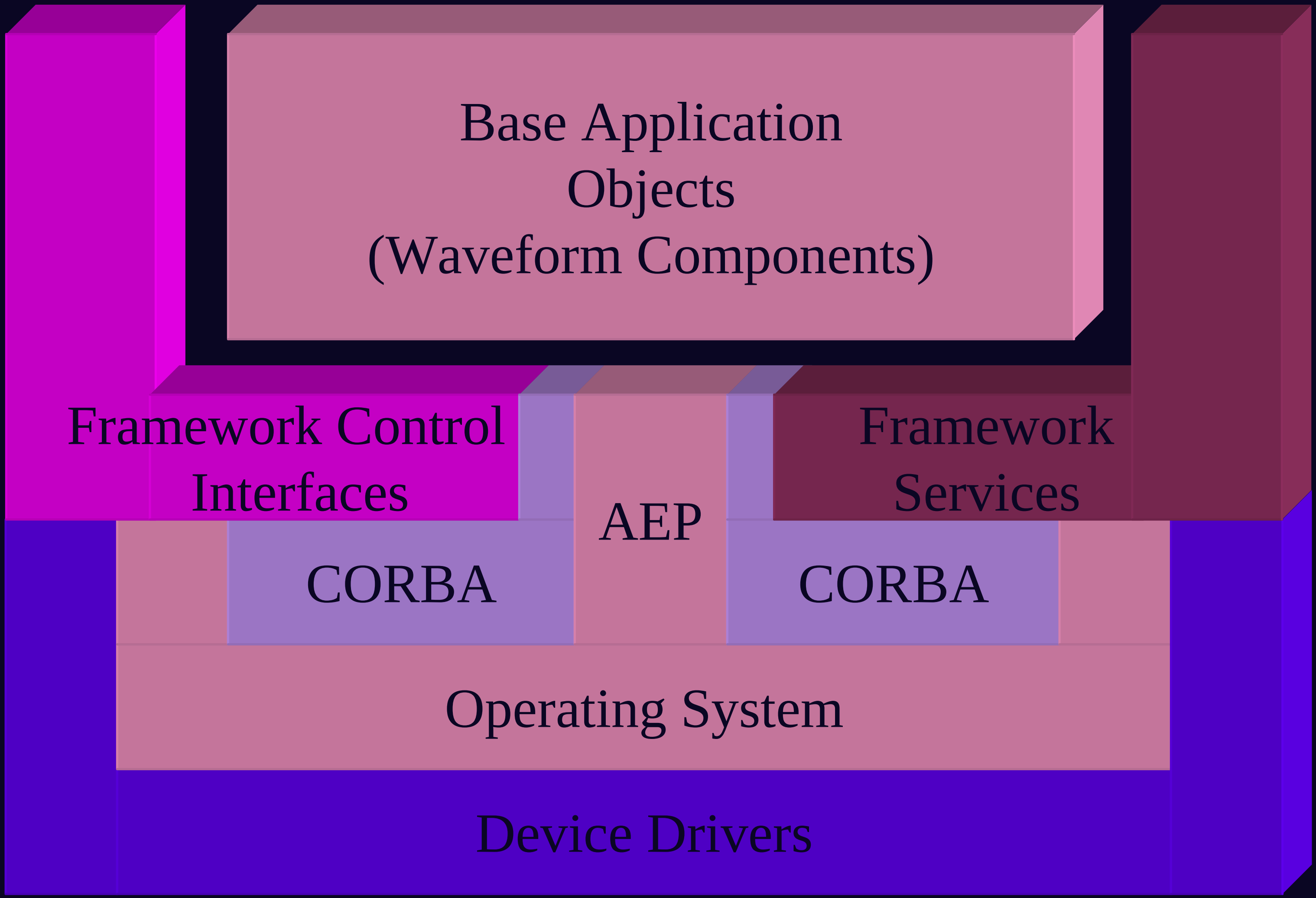

An Example of developing an SCA waveform

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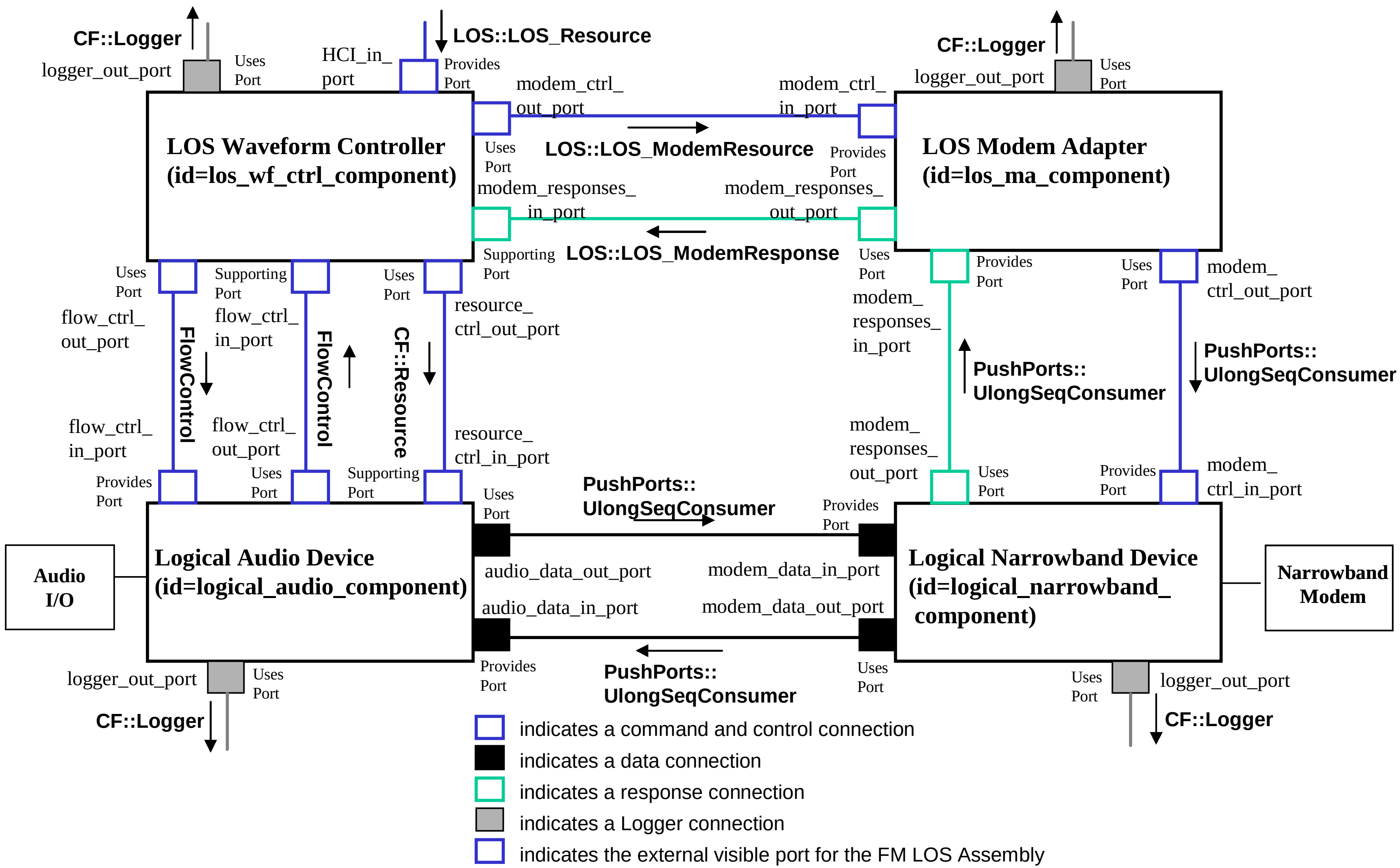

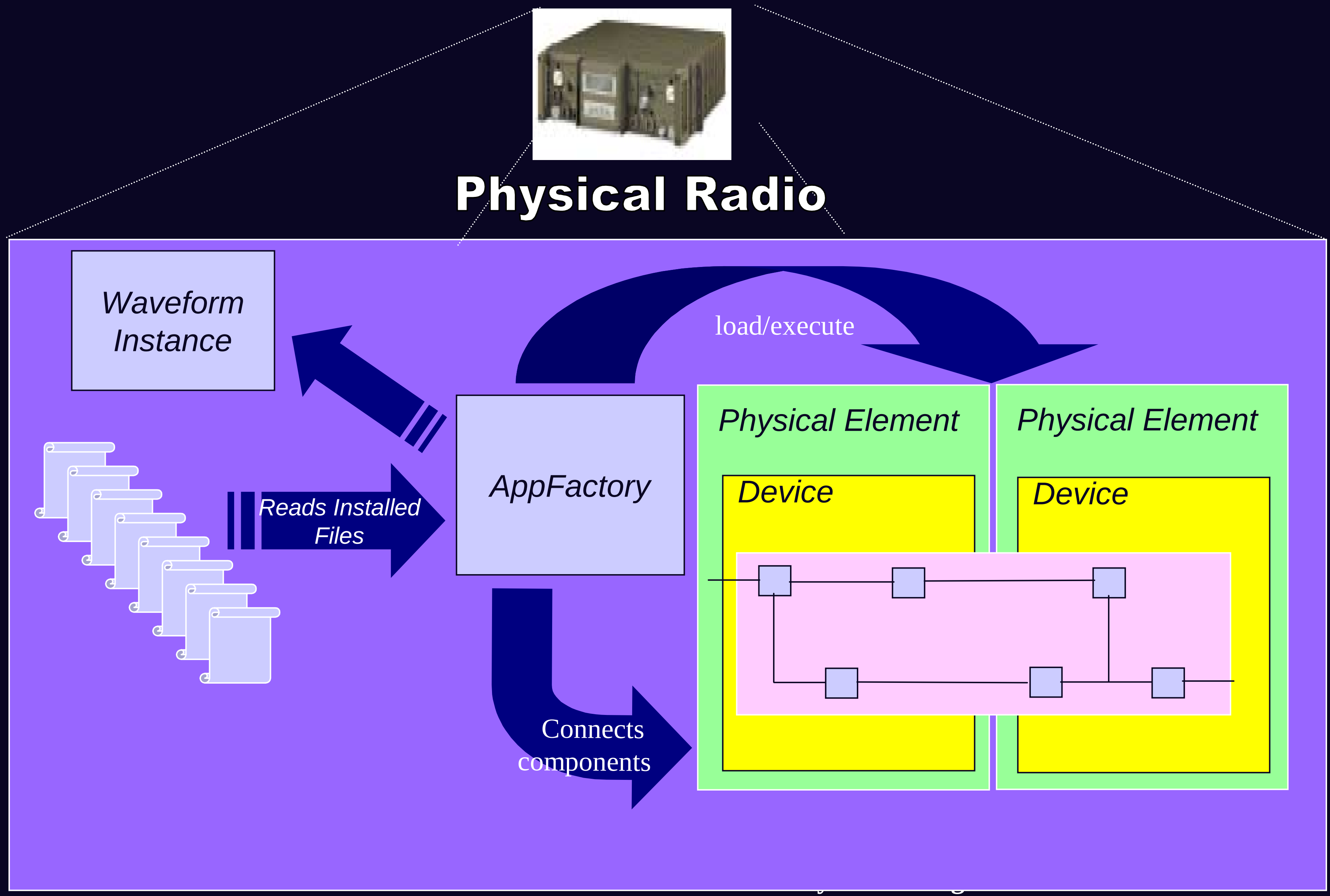

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Physical Radio
Waveform Instance
load/execute
AppFactory
Reads Installed Files
Physical Element
Physical Element
Device
Device
Connects components

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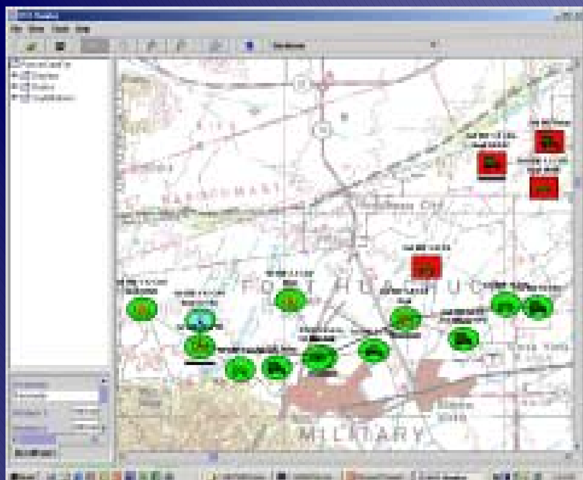
JTRS Step 2c Radio Overview

JTRS 2C Overview



- **Validate SCA Architecture in a two channel ad-hoc, peer-to-peer, packet-based, networked radio system**
- **Design, Build, and Test multiple engineering development radios**
- **Develop a Network Management Terminal (NMT) to control the radio**
- **Develop a programmable cryptographic subsystem and achieve NSA Endorsement for Secure Communication**
- **Conduct validation testing at the U.S Army's Electronic Proving Ground (EPG)**

Hardware Architecture

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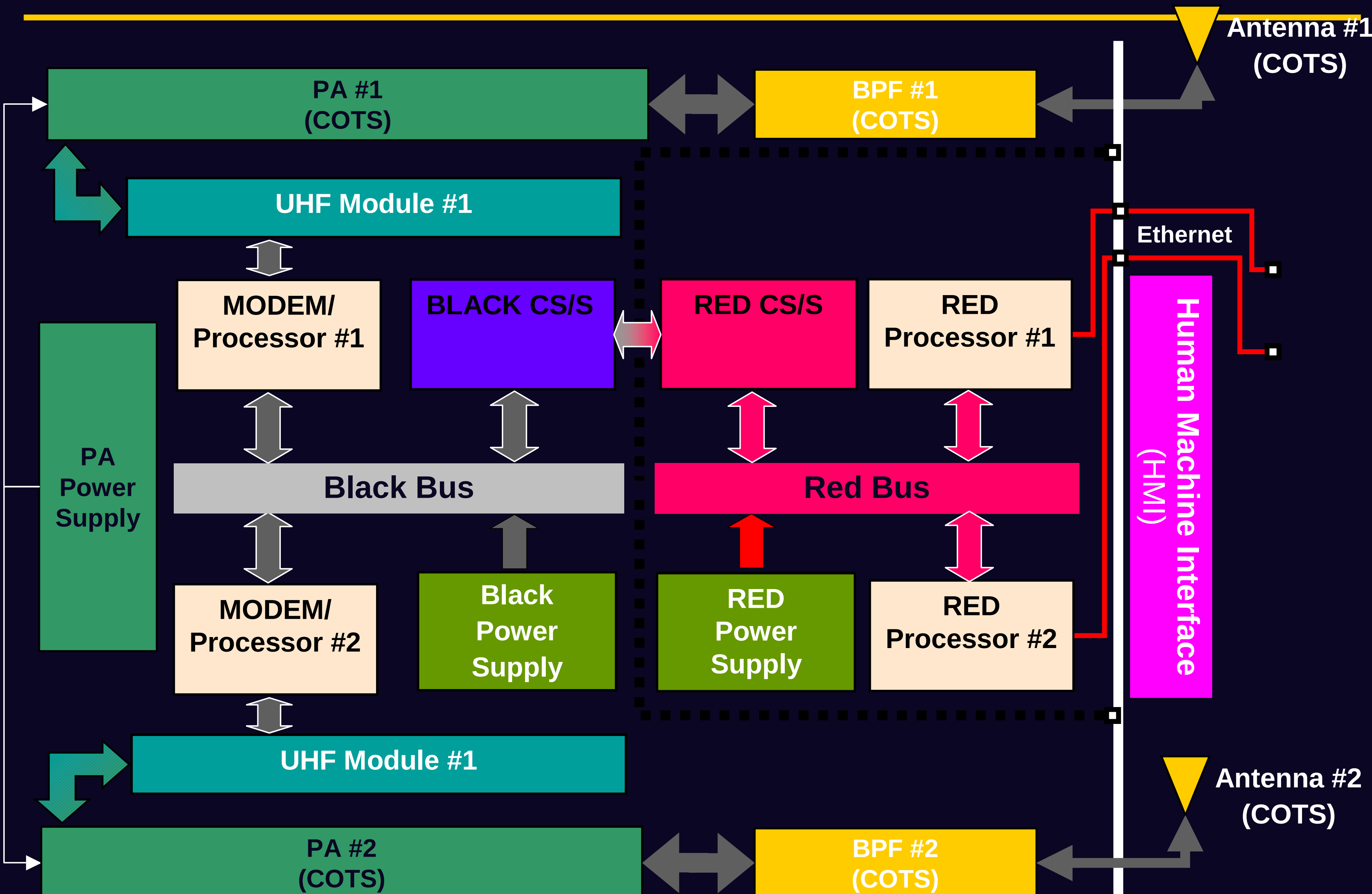

Software Architecture

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- **Operating Systems that fulfill platform and SCA requirements**
  - We use both General Purpose OS(Linux) and an RTOS (LynxOS)
  - Hardware drivers to support custom hardware
- **CORBA and CORBAServices**
  - We use the OCI's commercially available release of TAO (The ACE ORB).
- **An SCA Core Framework**
  - Developed at BAE SYSTEMS
- **Platform components that abstract the physical hardware components of the system.**
- **Waveform components that implement a CSMA waveform in the UHF band.**

What does the radio hardware/software do?

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- **The two-channel JTRS Step 2C radio is a “four-port router”**
  - Two 10/100 BASE-T LAN interfaces
  - Two wireless RF interfaces, capable of hosting different waveforms
    - CSMA – similar to IEEE 802.11b WLAN, IEEE 802.15 “Bluetooth LAN”
- **Internet routing**
  - The red processors run open-source, Linux-based routing software
    - Merit Networks GateD v3.6 for unicast routing
    - Univ. of Oregon PIMD for multicast routing
  - Fully interoperable with COTS routers (Cisco 2600/3600 series)
    - Open Shortest Path First -- OSPFv2
    - Protocol-Independent Multicast, Dense Mode
- **Intranet (wireless) routing**
  - Radio maps routing information from the wired interface into radio protocols that are optimized for wireless networks
  - OSFP → ROSPF or “Radio OSPF”
  - PIM-DM → RPIM or “Radio PIM”

What does the radio do?

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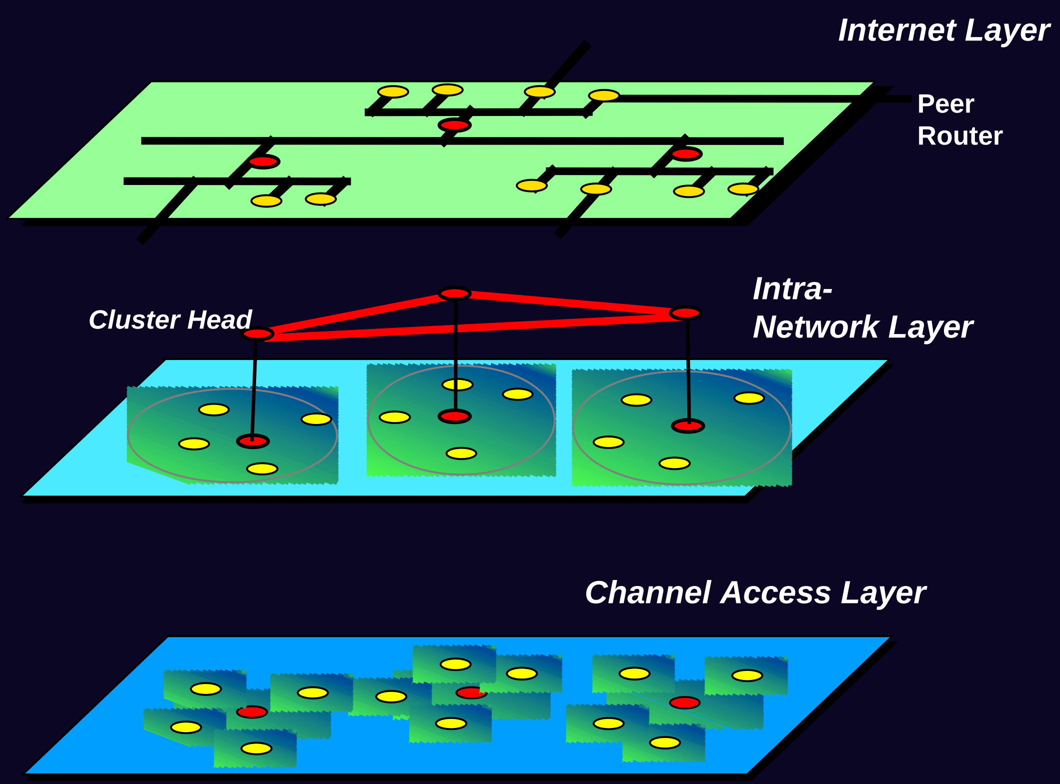
Network Layer
- IP Delivery
- Edge Routing
- OSPF/PIM-DM
- LAN interface

Link-Layer
- Cluster Membership
- Configuration
- Network Management
- Message Priorities

Physical Layer
- Channel Access
- Adaptive Power Control
- Power Levels
- Adaptive Data Rates
- FEC



Fielding a JTRS Radio

What steps are involved in developing a JTRS radio

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- **Develop or acquire:**
  - Radio hardware that conforms to open standards
    - Allows software developers to leverage existing code/drivers for devices and interconnect
  - An SCA Core Framework
  - SCA compliant components in support of the waveform you wish to deploy.
    - As well as the XML files that define their interfaces and capabilities
  - The XML files (Domain Profile) that define the waveform
    - i.e. The connectivity of the software components and the partitioning and deployment characteristics
- **Integrate the above elements**
  - Bring SCA components online as soon as possible
  - Connect them in simulation
  - Validate interfaces between them
  - Flesh out XML profiles
  - Deploy them on target
- **Find a happy medium between developing/debugging in simulated environment vs. target**
  - RTOS tools for debugging/development tend to be less mature than general purpose OS tools
  - Embedded systems tend to provide less visibility (e.g., no console)

Integration of the JTRS 2c radio

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- **Integration of the 2c radio focused significantly on the following:**
  - Functional Correctness
    - Ranging from network protocols to RF datalink
  - Meeting Performance constraints
    - Throughput
      - ✓ Move ~425kbps over the air between radios
    - Latency
      - ✓ Low enough to support VoIP, Video Teleconferencing
    - Handle Army's situational awareness datagrams
      - ✓ Datagrams tend to be relatively small.
      - ✓ Bundling not an option because of latencies.
      - ✓ Translation: Move ~500 packets/second through the radio and across the RF link.

Techniques required to meet performance constraints

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- **Use a high performance ORB**
  - In the case of the JTRS2c…TAO
- **Apply standard optimization techniques to the code and the ORB**
  - Optimize for speed
  - Use standard interface capabilities of sequence<octet> wherever possible
    - Eliminates deep copies when data passes from component to component.
  - Use profile tools to find inefficiencies
    - In the case of the JTRS2c disabling native exceptions provided significant performance increases
- **Partitioning of software components is key.**
  - Partition components with high throughput/low latency requirements in the same address space.
  - Use ORB collocation optimizations
    - In the case of the JTRS2c TAO's collocation optimization was leveraged for components in the same address space.
      - ✓ Turns the CORBA calls into C++ call.
      - ✓ CORBA overhead virtually disappears!

Collocation Optimizations a must!

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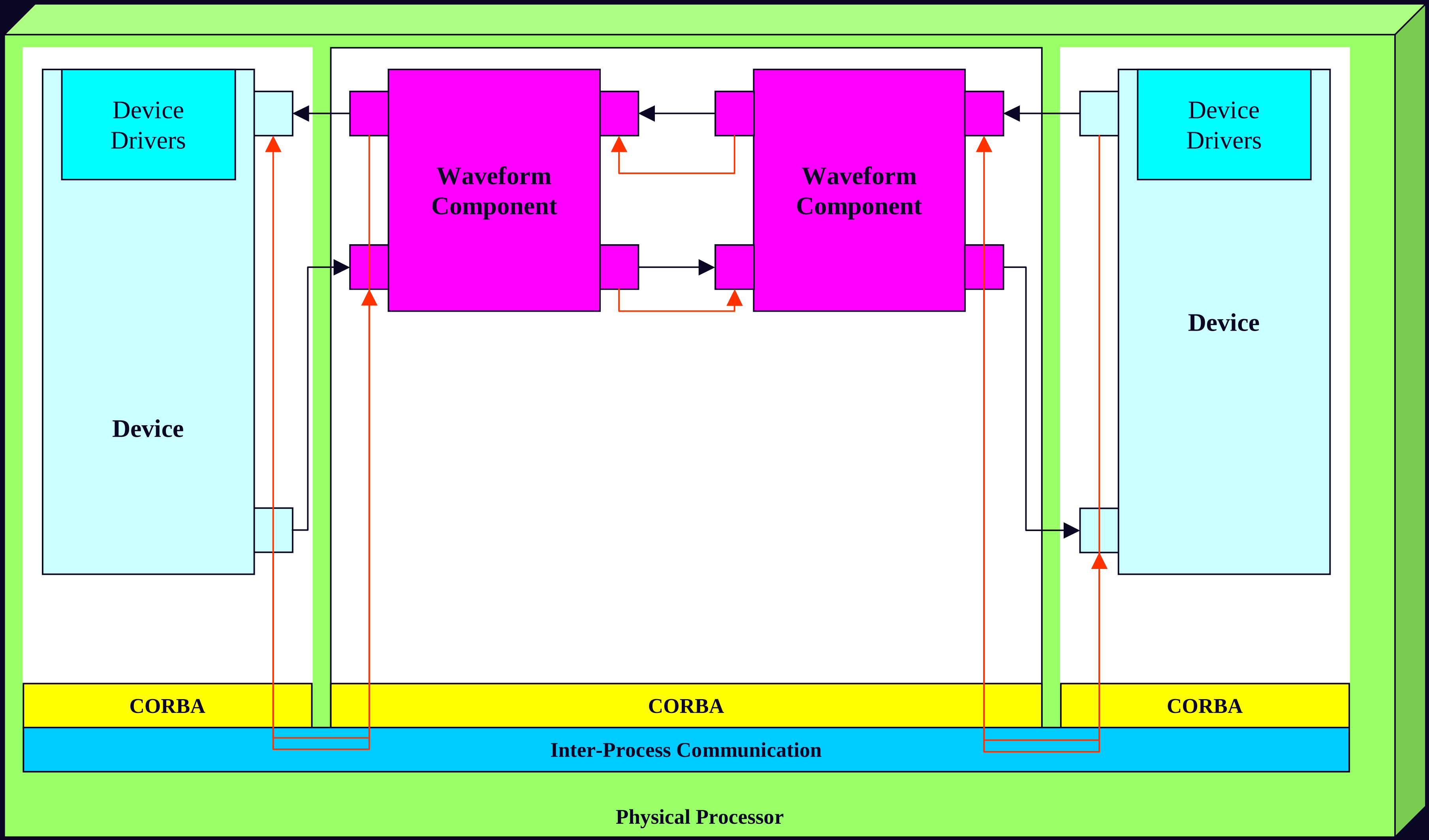

Easing software development in an SCA environment

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- **SCA technologies not historically used in the Defense Industry**
  - Distributed-component based architectures
  - Client-Server architectures
  - Mark-up Languages
  - Dynamic software deployment
  - Even Object Oriented Analysis/Design is somewhat novel…
- **We found we needed something to ease this**
  - Wrote a set of frameworks that employed design patterns and meta-programming techniques to abstract away much of the SCA-required functionality.
  - We packaged these frameworks into an easy-to-use "SCA Developer Kit"
    - Allows waveform component developers to concentrate on implementing the specifics of their particular waveform

Advantages and Successes we had using CORBA

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- **Of all the elements of the software system (RTOS, drivers, ORB, Core Framework, Application Components), the ORB and CORBA capable components were the least problematic.**
- **Apart from developing the waveform software, we spent a large percentage of our effort debugging drivers, BSPs, hardware, and RTOS.**
- **TAO provides a CORBA-compliant implementation and was therefore very easy to use.**
- **Location Transparency and Portability have allowed us**
  - to develop, run and test on non-target platforms for ease of development and use of third party tools
  - to reuse, repartition and redeploy these software components onto other radio platforms.

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The SCA and the OMG

The SCA and the OMG

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- **The JTRS SCA has roots in OMG's CORBA Component Model Specification**
  - MSRC tailored CCM for use in radio environment.
- **SWRADIO DSIG formed in April 2002**
  - BAE SYSTEMS original co-founder
  - Since then the group has been standardizing aspects of the SCA as OMG specifications:
    - Deployment and Configuration
    - SW Radio
    - Lightweight Services
    - Lightweight CCM

Summary/Conclusion

JTRS Step 2C Field Test

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- **First field tested JTRS radio & waveform for an Army customer**
- **Testing performed at the Army's Electronic Proving Ground**
  - 3 week exercise at Ft. Huachuca, Arizona
  - Simulated battlefield conditions
- **10 Radios deployed in both on-the-move and stationery platforms**
- **Simulated message traffic between radio's dispersed over 20 km nominally**
  - Range tests conducted proved radio worked to over 35 km.

JTRS Step 2C Field Test

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- **Tests included exercising the radio's ability to:**
  - Plan, load, and monitor a network of radios using an SCA enabled Network Management Terminal
    - NMT developed by BAE SYSTEMS to control networks of JTRS radios
  - Automatically form and self-heal tactical networks of computers
    - In both stationery and on-the-move scenarios
  - Maintain a network of mobile radios
  - Accurately exchange and route data on two radio channels simultaneously
- **Radio met or exceeded all tested performance requirements**
- **Demonstrated the feasibility of the JTRS architecture in a field environment**

Stationery Unit

Mobile Unit (Hummer)

Mobile Unit (SUV)

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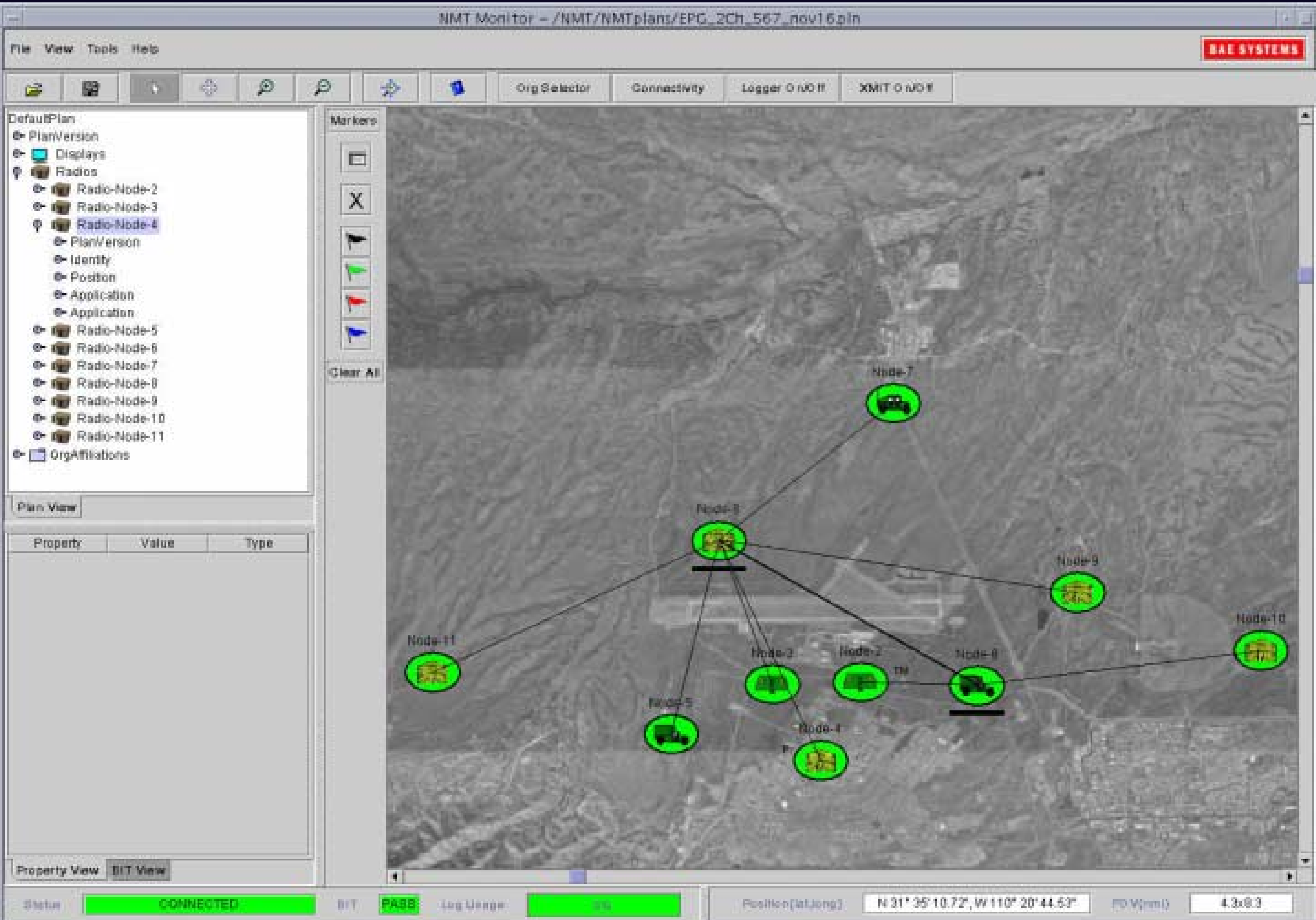
Mobile Unit - Got antenna?



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Conclusion

- **JTRS 2c radio proves:**
  - The JTRS SCA architecture works in a fieldable radio
  - The architecture can be applied to low latency/high throughput packet radios
  - The architecture is not limited to narrowband radio systems only
  - CORBA can be used to move large amounts of data traffic though the radio with tolerable latency
  - Networks of radios can be configured managed using CORBA
    - Not only on the wired side, but at RF over large distances
    - Without significant impact to network performance

Army Lt. Col. David E. Lockhart, JTRS Army Program Manager said in the press release:

"We have seen many presentations and simulations illustrating the JTRS concept, but what happened here (at Ft. Huachuca) proves that this is real and achievable"

Yet another successful CORBA Application!!!
(Brought to you by BAE SYSTEMS)

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Questions?